

Effects of eutrophication on vendace, *Coregonus albula* (L.). II. Biological characteristics of vendace from selected lakes in Wielkopolska

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Received – 05 December 2011/Accepted – 08 March 2012. Published online: 30 June 2012; ©Inland Fisheries Institute in Olsztyn, Poland
Citation: Fiszer M., Przybył A., Andrzejewski W., Mazurkiewicz J., Golski J., Przybylska K., Runowski S. 2012 – Effects of eutrophication on vendace, *Coregonus albula* (L.). II. Biological characteristics of vendace from selected lakes in Wielkopolska – Arch. Pol. Fish. 20: 97-108.

Abstract. The aim of the study was to evaluate the dynamics of changes in body weight, length, and condition, as well as to determine and compare the age structure, length increments, and fecundity of vendace from four lakes in the Wielkopolska region. The smallest mean total length (21.1 cm) and body weight (82.59 g) were recorded for specimens from Lake Lubikowskie, while the greatest values were noted for those from Lake Strzeszyńskie at 23.07 cm and 118.01 g, respectively. The smallest mean value for Fulton's condition factor was noted in the vendace from Lake Lubikowskie (0.86), while the highest was noted for specimens caught in Lake Strzeszyńskie (0.93). Slightly less than 50% of the vendace caught in Lake Lubikowskie were 1-year-old-fish, whereas 2-year-old fish predominated in the other lakes. In the vendace samples from Lakes Gorzyńskie and Strzeszyńskie no 1-year-old specimens were noted, while 3-year-old fish accounted for 35.3% and 23.3%, respectively, of the total fish caught. The total length increments of vendace in the analyzed lakes were similar, and according to the classification by Szczerbowski, did not vary from the Polish mean. The highest absolute fecundity was observed in fish from Lake Gorzyńskie, but it was considerably lower (almost two-fold) in the vendace caught in Lake Strzeszyńskie.

Keywords: age, condition, fecundity, growth, vendace

Introduction

Papers published to date concerning the comprehensive biology of vendace, *Coregonus albula* (L.), have clarified many issues connected with environmental requirements of this species (Walczak 1953, Bernatowicz 1958, Radziej 1973), catch rates and fishing methods (Turunen et al. 1998), the effects of biotic (Winfield et al. 1996a, Huusko and Sutela 1992, 1997, Huusko et al. 1996) and abiotic factors (Dąbrowski and Eichler 1972) on fluctuations in productivity, and finally the production of stocking material (Mamcarz 1994). The following issues are also frequently discussed with regard to vendace: the analysis of age, length increments, and body weight (Szypuła 1970, Viljanen 1988a, Huuskonen 1997); fecundity and reproduction (Viljanen 1988b, Demska-Zakęś and Długosz 1995, Czerniejewski and Filipiak 2002a); nutrition of adult fish (Bøhn and Amundsen 2001, Czerniejewski and Rybczyk 2002, Dąbrowski et al. 2002); nutrition of juvenile vendace (Karjalainen et al. 1997, Huusko and Sutela 1998).

In view of the deteriorating water quality in Polish lakes and their progressing eutrophication, it is of particular importance to continue these studies because of the high variability in individual bio-morphometric parameters of vendace inhabiting

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different types of lakes. The scope of the investigations presented in this paper include an evaluation of the dynamics of changes in individual weights and total lengths, the condition of vendace in lakes of the Wielkopolska region, and determining and comparing the age structure, length increments, and fecundity of vendace caught in the analyzed lakes.

Study area

Analyses were conducted in four lakes in the Wielkopolska Region – lakes Dominickie, Gorzyńskie, Lubikowskie, and Strzeszyńskie. The parameters differentiating the lakes most strongly were area, depth, area-depth index, shoreline development, and fish yield index (Fiszer et al. 2012). In terms of morphometry, lakes Gorzyńskie and Lubikowskie are most suitable for optimal vendace fishery management. The least developed stratification was observed in Lake Dominickie, while the most marked stratification was noted Lake Gorzyńskie, which has the smallest epilimnion depth, the highest thermocline temperature gradient, and a deep, cool hypolimnion. Considerable deoxygenation was observed in the hypolimnion in the summer season in all the lakes; however, in Lake Strzeszyńskie oxygen deficits were also noted in the metalimnion. According to the analysis of physicochemical indexes and trophic state indexes, all of the analyzed lakes were of good water quality. The trophic states of lakes Gorzyńskie and Lubikowskie were designated as bordering on the mesotrophic and eutrophic states, while lakes Dominickie and Strzeszyńskie were designated as eutrophic.

Materials and methods

Specimens of vendace were collected in 2005 in the spring (9-16 May), summer (12-28 August), and autumn (20-26 November). These fish were caught during commercial night catches performed using gillnets with mesh sizes of 18, 20, 22, and 24 mm. The vendace

were selected at random from the whole catch on a given day, transported on ice to the laboratory, and packed in batches of ten specimens each in double plastic bags that prevented tissue water expression, and deep-frozen at a temperature of -28°C . A total of 1400 fish were analyzed with 350 specimens from each lake. Spring and summer samples comprised 100 specimens, while fall samples consisted of 150 specimens (Ciepielewski 2000a, 2000b). All of the specimens caught in the fall were subjected to biological analyses that included determining fish condition, age, growth rate, and absolute and relative fecundity in females. The first parameter was also calculated for fish caught in the spring and summer seasons using Fulton's condition factor (Opuszyński 1983). Fish age was determined using collected scale material as presented by Heese (1992). Readings were performed using the illustrations in studies by Bernatowicz (1952) and Ciepielewski (1971). Growth rates for total fish length were determined using reverse readings according to Dahl-Lea (Szypuła et al. 2001). Absolute, individual fecundity and relative fecundity per 100 g of body weight was determined by gravimetry using female gonad analysis in the period preceding spawning.

Results

Fish length, body weight, and condition

The total length (TL) of all caught vendace ranged from 14.3 to 31.2 cm (Table 1). The smallest mean length (21.1 cm) was noted in vendace from Lake Lubikowskie, while the greatest (23.07 cm) was recorded for fish from Lake Strzeszyńskie. The greatest length range was noted in vendace from Lake Gorzyńskie. The mean body weight of vendace caught from all the analyzed lakes was 99.9 g at a range of 38.6 to 342.1 g (Table 1). Specimens caught in Lake Lubikowskie were characterized by the lowest mean weight (82.59 g), whereas the greatest (118.01 g) was recorded for vendace from Lake Strzeszyńskie. The fishes caught in Lake Gorzyńskie had the greatest body weight range from 64.1 to 342.1 g.

Table 1

Mean total length (TL), body weight (BW), and Fulton condition factor (CF) of vendace from the studied lakes by season. Sample size for each lake is 100 for spring and summer and 150 for autumn

Season	TL (cm)	Range (cm)	SD	BW (g)	Range (g)	SD	CF	Range	SD
Lake Dominickie									
Spring	20.47	18.0-23.1	10.91	89.44	56.4-142.6	14.49	1.04	0.84-1.37	0.10
Summer	22.14	20.1-24.8	11.36	90.34	64.4-121.2	13.74	0.83	0.70-0.98	0.05
Autumn	22.19	19.9-24.5	8.68	94.90	66.5-130.9	13.18	0.87	0.62-1.08	0.09
Mean	21.60	18.0-24.8	10.31	91.56	56.4-142.6	13.80	0.90	0.62-1.37	0.12
Lake Gorzyńskie									
Spring	21.96	14.3-26.4	20.11	104.19	64.1-158.5	22.70	0.96	0.81-1.43	0.09
Summer	22.05	19.7-25.6	11.29	97.79	67.1-153.0	17.23	0.91	0.55-1.09	0.07
Autumn	23.75	20.0-30.7	17.03	120.33	67.0-342.1	36.58	0.88	0.64-1.21	0.11
Mean	22.58	14.3-30.7	16.14	107.43	64.1-342.1	25.50	0.91	0.50-1.43	0.09
Lake Lubikowskie									
Spring	21.58	19.5-31.2	15.45	77.92	53.3-140.8	15.73	0.77	0.67-0.93	0.06
Summer	19.90	17.2-25.5	19.05	72.22	45.1-159.0	22.87	0.89	0.71-1.08	0.08
Autumn	21.96	17.3-27.9	26.15	97.65	38.6-219.6	36.97	0.88	0.63-1.19	0.09
Mean	21.14	17.2-31.2	20.21	82.59	38.6-219.6	25.19	0.86	0.63-1.19	0.09
Lake Strzeszyńskie									
Spring	21.81	17.3-29.0	21.05	111.91	51.0-222.2	32.29	1.05	0.81-1.42	0.11
Summer	24.00	19.5-28.3	18.45	135.65	75.9-243.5	37.54	0.96	0.76-1.43	0.14
Autumn	23.38	19.7-29.4	18.70	106.47	66.7-277.0	31.09	0.82	0.63-1.15	0.09
Mean	23.07	17.3-29.4	19.40	118.01	51.0-277.0	33.64	0.93	0.63-1.43	0.15

The lowest mean value of Fulton's condition factor was observed among vendace from Lake Lubikowskie (0.86), whereas the highest was noted in specimens caught in Lake Strzeszyńskie (0.93) (Table 1). This factor fluctuated within the broadest range in vendace from Lake Gorzyńskie (0.55-1.43), while the narrowest range was noted in the fish from Lake Lubikowskie (0.63-1.19).

Age structure and body length increments

Slightly less than 50% of the vendace caught in Lake Lubikowskie consisted of 1-year-old fish, while 2-year old specimens predominated in the other lakes (Table 2). No 1-year-old specimens were noted in the vendace samples caught in lakes Gorzyńskie and Strzeszyńskie, while 3-year-old fish accounted

for 35.3% and 23.3%, respectively, of all the fish caught. Moreover, six fish from Lake Gorzyńskie were identified as 4+, which accounts for 4% of the sample caught in that lake.

Vendace caught in Lake Dominickie had the greatest growth rates in terms of length in the first year of life (on average 14.69 cm). In the second year this increment was over three-fold lower, while in the third year it was 18-fold lower (Table 2). Vendace from Lake Gorzyńskie were characterized by the greatest increases in body length increments in the first two years of life. In the third and fourth years this increment was, on average, three times lower in comparison to that of the first year. The character of length increment increases in vendace from Lake Lubikowskie was typical and similar to that in vendace from the lakes described above, i.e. very high growth was noted in the first year of life, increment

Table 2

Growth rate of vendace from the studied lakes calculated with the Dahl-Lea method (by age groups)

Age group	n	L ₁	L ₂	L ₃	L ₄
Lake Dominickie					
I	35	16.06			
II	109	14.34	18.65		
III	6	13.01	16.70	19.36	
Mean		14.69	18.56	19.36	
Total length growth		14.69	3.86	0.81	
Lake Gorzyńskie					
II	91	10.69	17.37		
III	53	9.41	14.63	19.84	
IV	6	10.62	17.09	21.67	25.41
Mean		10.24	16.39	20.03	24.51
Total length growth		10.24	6.15	3.63	4.47
Lake Lubikowskie					
I	70	15.6			
II	48	13.53	18.83		
III	32	13.36	18.17	21.81	
Mean		14.49	18.57	21.81	
Total length growth		14.49	4.08	3.24	
Lake Strzeszyńskie					
II	115	13.74	18.75		
III	35	10.98	16.32	21.31	
Mean		13.09	18.18	21.31	
Total length growth		13.09	5.08	3.12	

increase was over three-fold lower in the second year, and it was the lowest in the third year of life (3.24 cm). The fastest growth rate in fish from Lake Strzeszyńskie was recorded in the first year of life (13.09 cm), while in the second and third years a marked decrease in length increment growth was observed (Table 2).

The growth of vendace in the first year of life in lakes Dominickie, Lubikowskie, and Strzeszyńskie was almost uniform and slight differences were recorded in their total lengths (range of 13.09-14.69 cm) (Table 2). In Lake Gorzyńskie the growth rate of vendace was markedly slower and the value of it was much lower at 10.24 cm. In the second year of life the above mentioned trend was maintained; in Lake Gorzyńskie the highest value of body length was

recorded in vendace. In the third year of life the described regularity was reversed; vendace grew fastest in Lake Gorzyńskie (3.63 cm), while the growth rate was slowest in fish from Lake Dominickie (0.81 cm). The significant growth variability of vendace from Lake Gorzyńskie is probably due to environmental conditions and food availability.

Fecundity

The highest absolute fecundity was noted in fish from Lake Gorzyńskie, while nearly two-fold lower fecundity was recorded in vendace caught in Lake Strzeszyńskie (Table 3). In lakes Lubikowskie and Strzeszyńskie the highest absolute fecundity was observed for vendace aged 3+, while in Lake

Table 3

Mean and range values of individual absolute fecundity of vendace from the studied lakes by age group

		Age groups			
	Total	1 +	2+	3+	4 +
Lake Dominickie					
n	90	32	53	5	
Mean	10363	10109	10467	9727	
Range	5321-16278	5321-14008	6025-16278	8102-12131	
SD	2194	2192	2235	1707	
Lake Gorzyńskie					
n	78		48	27	3
Mean	15757		14397	15570	39221
Range	8368-54589		8368-22796	9040-26587	20300-54589
SD	6485		3238	3908	17419
Lake Lubikowskie					
n	132	62	42	27	1 *
Mean	10294	8126	11684	13191	
Range	2622-21992	2624-14911	4686-21193	9449-21992	
SD	3827	2256	4246	3161	
Lake Strzeszyńskie					
n	34		23	10	1 *
Mean	9581		7404	14547	
Range	3670-46041		3670-26150	1297-46041	
SD	8542		5790	12617	

*fish not considered in the analysis

Table 4

Mean and range values of individual relative fecundity of vendace from the studied lakes by age group

		Age groups			
	Total	1 +	2 +	3 +	4 +
Lake Dominickie					
n	90	32	53	5	
Mean	10322	10628	10271	9817	
Range	5892-13795	5892-13780	6031-13795	9121-10679	
SD	1727	1771	1762	643	
Lake Gorzyńskie					
n	78		48	27	3
Mean	11350		11243	11373	12867
Range	7285-17492		7362-17492	7285-14575	9244-15957
SD	2145		2115	2090	3388
Lake Lubikowskie					
n	132	62	42	27	1*
Mean	10416	10951	10098	9664	
Range	4380-16619	4380-16167	6809-16619	6546-12746	
SD	2117	2430	1831	1713	
Lake Strzeszyńskie					
n	34		23	10	1*
Mean	6418		5687	7896	
Range	2380-16621		2380-12694	1239-16621	
SD	3318		2925	4103	

*fish not considered in analysis

Gorzyńskie it was noted in age group 4+. In the latter case, the sample was not representative since it comprised only three specimens.

The relative fecundity of vendace from the analyzed lakes located in the Wielkopolska region fell within a broad range from 6418 in Lake Strzeszyńskie to 11350 in Lake Gorzyńskie (Table 4). It must be emphasized that, similarly to absolute fecundity, slight differences of a maximum of 0.9% were observed in the relative fecundity of vendace caught in lakes Dominickie and Lubikowskie. The mean value of this parameter in the above mentioned lakes was 10322 and 10416 eggs per 100 g⁻¹ body weight.

Discussion

Commercial catches of vendace in Poland are performed mainly using gillnets with a mesh size of 24 mm. This permits catching fish with body lengths ranging from 17.8 to 24.2 cm, while the length of fish caught with maximum efficiency was 21.0 cm (Ciepielewski 1974a). Vendace used for the realization of the objectives of this study were caught using gillnets with a varied mesh size (18-24 mm), which resulted in high heterogeneity in total length and individual weight of fish samples caught from lakes included in these investigations. However, the use of multi-mesh gillnets with varied mesh size increased the qualitative representativeness of the fish samples.

Vendace condition in this study was evaluated using Fulton's factor, which is used widely in such studies (Ritterbusch-Nauwerch 1995). The mean value of this parameter indicates the markedly better condition of vendace in Lake Strzeszyńskie in comparison to those from the other lakes, although in terms of morphometric and physicochemical parameters this lake cannot be classified as an advantageous habitat for vendace. In turn, fish from Lake Lubikowskie, which is characterized by the best environmental conditions for this species, exhibited the lowest condition factor. The reasons for this and the different maximum individual lengths and weights

probably lie in differences of the availability of adequate nutrition bases for vendace. This factor could have been of greater importance than environmental factors.

A comparison of the estimated condition factors with literature data is hindered because some authors use total length (Szypuła 1970, Sarvala et al. 1992), body length (Bernatowicz 1958), or caudal length (Winfield et al. 1996b, Czerniejewski and Filipiak 2002a, 2002b, Czerniejewski et al. 2002) to determine this parameter (Table 5). When using empirical data presented in the three most recent publications, the values of Fulton's condition factor were determined based on fish total length. Data concerning the condition of fish from 11 lakes in western Pomerania in view of the 4 analyzed lakes from the Wielkopolska region indicate that, except for Lake Lubikowskie, vendace from the other three lakes are characterized by good condition. Differences in the values of Fulton's factor could have been the result of different catch seasons, and also because the effect of fish length and age was not considered in these analyses.

A significant element of a rational fishery management is to identify the age structure of fish as well as their growth rate. Vendace is classified as a pelagic fish species with a relative short life cycle, while in commercial catches as much as 80-90% are comprised by fish aged 1+ to 3+ (Viljanen 1986, Auvinen 1987, Christianus 1995). However, in accordance with the suggestions presented by Leopold (1972), because of their short life cycle, vendace catches should target specimens aged 2+ with maximum intensity. In accordance with the above mentioned recommendations, commercial catches of this species should be performed using gillnets with mesh size of 24 mm.

The age structure of the population was similar in vendace samples from the lakes included in this study. The adequately high proportion of vendace specimens aged 1+ and 2+ years in catches from the analyzed lakes was because the growth rate of this species is greatest in the first three years of life (Bernatowicz et al. 1975). However, as a result of changes in fish growth, the performance of catches

Table 5

Values of Fulton condition factors of vendace in selected lakes of Poland

			Fulton condition factors	
Lake	Authors	Season	Mean	Range
Pomerania Region				
Siecino	Czerniejewski et al. (2002a)	Autumn	0.86	0.65-0.99
Komorze	Czerniejewski and Filipiak (2002a)	Autumn	0.88	0.7-1.0
Pile			0.84	0.58-0.96
Leśne			0.87	0.67-1.01
Moryńskie			0.91	0.68-1.21
Drawsko	Czerniejewski and Filipiak (2002b)	Summer	0.79	0.66-0.92
		Autumn	0.86	0.7-1.1
Pelcz		Summer	0.74	0.55-0.88
		Autumn	0.81	0.50-1.06
Wielkopolska Region				
Dominickie	Own data		0.90	0.62-1.37
Gorzyńskie			0.91	0.50-1.43
Lubikowskie			0.86	0.63-1.19
Strzeszyńskie		Mean of all seasons	0.93	0.63-1.43

using identical gear, or the decision to cease fishing exploitation in a lake, aging can occur in the exploited segment of the population (Ciepielewski 1974b, Winfield et al. 1996b).

Vendace is characterized by high growth rate variation in different lakes. The comparison of the data presented in Table 6 regarding the total length of fish in each year of life indicates that vendace inhabiting the northernmost lakes were characterized by the slowest growth rates. This was confirmed indirectly by an analysis of growth rates of different populations of vendace from lakes in Finland (Viljanen 1988a). Viljanen suggests that with increasing latitude, the body length obtained by vendace in subsequent years of life is significantly reduced, probably due to the lower productivity of these lakes. Bauch (1961) suggested that specific environmental conditions play a decisive role in vendace growth, and the greatest increments as well as the maximum age are typically found in lakes with an abundance of crustaceous plankton. This is confirmed by the results of studies conducted by Radziej (1973).

Apart from the abundance of zooplankton in lakes, growth rates of these fish are also influenced by lake size (Marciak 1970), lake depth, water transparency and oxygenation during summer stagnation (Bernatowicz et al. 1975), and population size (Valkeajärvi and Bagge 1993). In Poland, the highest growth rate is noted among populations inhabiting lakes in the Wielkopolska Lake District and the Pomerania region, which indicates that conditions there are considerably better for the growth of this species than they are in the lakes of the Mazurian Lake District (Bernatowicz 1953, Czczuga 1959, Marszałek 1961, Marciak 1970, Bernatowicz et al. 1975, Mastyński 1978, Christianus 1995, Czerniejewski et al. 2002) (Table 7).

Criteria presented by Szczerbowski (1978) were applied to perform an accurate evaluation of the growth of the analyzed fish. According to this author, specimens that reached a length of approximately 20 cm (19.8-21.5 cm) in the third year of life are considered to be of average growth. Such growth dynamics were noted found for vendace from all of the the four analyzed lakes.

Table 6

Growth rates of vendace in different European countries

Country	Authors	Total length of vendace (mm)					
		1	2	3	4	5	6
Scandinavia (14 lakes)	Bauch (1961)	95	145	170	193	248	267
Norway (5 lakes)	Amundsen et al. (1999) Sandlund (1992)	114	153	173	192	209	
Finland	Viljanen (1988a)	103	136	158	171	178	
Soviet Union (3 lakes)	Nikolski (1970)	111	168	206	225		
Germany (45 lakes)	Bauch (1961)	111	175	202	219	236	273
Poland (186 lakes)	Marciak (1970)	120	174	202	223	249	267

Table 7

Growth rates of vendace in different regions of Poland

Region	Lake	Author	Total length of vendace (mm)					
			1	2	3	4	5	6
Mazury	Dejguny	Bernatowicz (1953)	144	206	247			
	Krzywe		114	172	236	260	273	
	Dobskie		145	204	232	249	265	
	Mamry Płn.		145	197	229	253	275	
	Harsz		127	194	225	249	252	
	Kisajno		138	197	224	235		
	Gołdopiwo	Czeczuga (1959) Christianus (1995)	91	145	205	233	250	273
	Buwełno		87	138	189	209	233	265
	Rydzówka		78	136	187	208	237	270
	Jagodne		95	139	186	209	230	255
	Tały		95	141	184	207	213	
	Łaśmiady		112	160	183	204		
	Tajty		85	145	176	196	213	238
	Ublik		108	143	162	173	186	
	Rajgrodzkie		99	158	192	220		
	Maróz		95	137	158	192		
	Lutry		107	146	156			
	Narie		95	145	166	171		
	Isąg		114	167	191	214		
Pomorze	Wdzydze	Marszałek (1961)	80	145	196	231	261	284
	Płesno	Marciak (1970)	132	197	230			
	Cieszęcin		99	181	229	259	274	
	Łętowo		158	205	225			
	Żerdno		149	213	247	267		
	İńsko		137	205	235	263		
Wielkopolska	Janikowo	Marciak (1970)	181	232				
	Ławica		162	210	230			
	Śremskie		145	209	256	277	290	
	Trześniowskie		95	167	201			
	Gorzyńskie	Mastyński (1978)	112	179	232			
	Dominickie	Own data	146	185	193			
	Gorzyńskie		102	163	200	245		
	Lubikowskie		144	185	218			
	Strzeszyńskie		131	181	213			

Table 8

Mean values of individual relative fecundity of vendace from Europe by age group

Country	Study site	Authors	Age groups							
			1+	2+	3+	4+	5+	6+	7+	8+
Finland	Bay of Bothnia	Lehtonen (1981)	1.63	3.25	4.45	4.48	5.35	6.26		
	Lake Pyhäjärvi	Sarvala et al. (1992)	9.88	13.51	17.36	18.90				
Soviet Union	Juribej River	Vysegorodcev (1977)			12.65	9.73	12.43	15.37	21.72	26.88
	Lake Ładoga	Diatlov (1978)	0.85	2.00	3.16	3.51	5.21	5.57	7.95	7.79
	Lake Onega	Berg (1948)	1.30	2.00	2.90	3.80				
Germany	Lake Stechlin	Anwand (1998)	3.58	5.36	7.13					
Poland (Mazury)	Lake Isąg	Demska-Zakęś and Długosz (1995)	13.46	19.83	31.07					
	Lake Narie		4.44	8.77						
	Lake Maróz	Ciepielewski (1974c)	5.67	7.81	10.62	13.19	15.73	18.69	18.98	
	Lake Mamry	Bernatowicz (1953)	4.10	4.60	8.50					
	Lake Dargin			6.70	8.30	8.80				
	Lake Kisajno			8.30	10.70	14.10				
	Lake Dobskie		5.60	7.00						
	Lake Komorze	Czerniejewski and Filipiak (2002a)		8.52	11.81					
	Lake Drawsko			8.05	14.88	21.02				
	Lake Pile		6.38	7.33	8.28					
Poland (Pomerania)	Lake Leśne		4.65	5.68	7.95					
	Lake Moryńskie		5.82	6.02	5.73					
	Lake Pełcz		2.73	2.94	3.62					
	Lake Siecino	Czerniejewski et al.(2002)	6.03	6.74						
	Lake Lubikowskie	Mastyński (1978)		4.30	13.65	19.98				
	Lake Bechno			7.40	11.27	14.53	16.71			
	Lake Lubrza			4.45	8.21	12.15				
	Lake Chłop			5.28	8.50					
	Lake Śremskie	Budyh and Iwaszkiewicz (1964)	18.20	20.40		62.60				
	Lake Strzyżmin		9.30	10.00	15.20					
	Lake Chalińskie		7.10	12.30	14.80					
	Lake Tuczo	Czerniejewski et al.(2002a)	5.07	9.80	11.46					
	Lake Dominickie	Own data	10.10	10.46	9.27					
	Lake Gorzyńskie			14.39	15.57	39.22				
	Lake Lubikowskie		8.12	11.68	13.19					
	Lake Strzeszyńskie			7.40	14.54					

Vendace is a fish species of relatively low fecundity; however, this is compensated by its early sexual maturity. Depending on environmental factors in lakes, males of this species are capable of reproducing most frequently as soon as the second year of life, while females can do so in the third year of life (Bernatowicz et al. 1975). Many authors have reported that in certain cold lakes in northeastern

Europe the gonads of vendace mature as late as in the third year of life (Aass 1972, Koskova 1977), and in case of vendace from Siberia they do so at the age of 4+ (Vyšegorodcev 1977). Because of the thermal characteristics in Polish lakes, vendace is capable of reproducing as early as at the age of 1+ (Budyh and Iwaszkiewicz 1964, Ciepielewski 1974c, Demska-Zakęś and Długosz 1995). This has been

confirmed by the results of studies conducted by the authors of this paper on lakes from the Wielkopolska region (Table 8). However, in spawning grounds, three-year-old fish predominate, and their fecundity is much greater than that of vendace aged 1+ (Bernatowicz et al. 1975, Długosz and Worniało 1985).

Vendace fecundity, as well as that of other fish species, fluctuates depending on environmental and population factors (Zawisza and Backiel 1970a, Viljanen 1988b, Gregersen et al. 2011). This is why the range of this parameter in different lakes is very broad. In their investigation of vendace from Mazurian lakes such as Isąg and Narie, Demska-Zakęś and Długosz (1995) reported that fish exhibiting a higher growth rate are also characterized by higher fecundity. This thesis could not be confirmed in the current study. Growth rates of fish in the four analyzed lakes in the Wielkopolska region were similar but fecundity was varied. The decidedly highest absolute and relative fecundity was noted in vendace from Lake Gorzyńskie.

Conclusions

1. Despite adverse environmental conditions in vendace lakes with elevated trophic status, vendace can achieve greater dimensions and better condition. This is confirmed by comparing individual size and condition in the populations from lakes Strzeszyńskie and Lubikowskie.
2. The predominance of fish aged 1+ in Lake Strzeszyńskie and those aged 2+ in the other lakes is consistent with adopted standards.
3. The growth rate of vendace in the analyzed lakes is similar, and according to the classification presented by Szczerbowski, does not deviate from the mean in Poland.
4. The highest vendace fecundity was recorded in Lake Gorzyńskie, while the lowest was noted in Lake Strzeszyńskie.

Acknowledgments. This study was conducted within a project supported by Poznań University of Life Sciences.

Author contributions. M.F., A.P., W.A., and J.M. designed and performed the study; M.F., W.A., J.M., and J.G. analyzed the data; M.F., J.M., J.G., K.P., and S.R. prepared the paper.

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